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Gulf Region
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ASSESSMENT OF SNOW CRAB IN THE SOUTHERN GULF OF ST. LAWRENCE (AREAS 12, 19, 12E AND 12F) AND ADVICE FOR THE 2013 FISHERY

Figure 1: Map of the southern Gulf of St. Lawrence showing the Crab Fishing Areas (CFAs), fishing grounds and management buffer zones (shaded area). Fishing grounds are labeled as follows: 1 Chaleur Bay, 2 Shediac Valley, 3 Orphan Bank, 4 Bradelle Bank, 5 Magdalen Channel, 6 Cape Breton Corridor, 7 Laurentian Channel, and 8 American Bank.

Context:

Snow crab, Chionoecetes opilio, has been commercially exploited in the southern Gulf of St. Lawrence since the mid-1960s. There are four individually managed fishing areas among which Area 12 (Figure 1) is the largest fishery in terms of its fishable surface, number of participants and landings. In Areas 12, 12E and 12F, the fishing season generally starts in April-May as soon as the Gulf is clear of ice and continues into early summer while in Area 19, the fishery opens after June 30 and usually ends in mid-September. The landing of females is prohibited and only hard-shelled males ≥ 95 mm of carapace width are commercially exploited.

DFO Gulf Region Fisheries and Aquaculture Management requested an assessment of the resource status in 2012 and catch advice for the 2013 fishery. This document provides an overview of the assessment results and the science advice. Catch rates and other fishery performance indicators are reported. The assessment of the status of the southern Gulf snow crab resource (Areas 12, 19, 12E and 12F) is based on fishery independent trawl surveys that provide indicators of: abundance (commercial biomass), reproductive potential (numerical abundance of mature females), recruitment, and to estimate exploitation rates in the fishery. A science peer review meeting was conducted January 30-31, 2013 in Moncton, NB. Participants at the science review were from DFO Science, DFO Fisheries Management, fishing industry, provincial governments, from universities, and Aboriginal organisations.

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SUMMARY

- Snow crab in fishing areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.
- The landings of snow crab from the southern Gulf of St. Lawrence in 2012 were 21,956 t from a quota of 22,007 t.
- The assessment in 2012 was conducted as per the recommendations of the Snow Crab Assessment Methods Framework Science Review held November 2011. The major change to the assessment methodology in 2012 was a revised sampling design that distributed sampling effort equally among 325 sampling grids.
- The exploitation rate of the 2012 fishery was 34.8%.
- The 2012 post-fishery survey biomass of commercial-sized adult male crabs was estimated at 74,997 t (95% C. I. 65,822 to 85,086 t), an increase of 18.7% from 2011. The available biomass for the 2013 fishery, derived from the 2012 survey, is within the healthy zone of the Precautionary Approach framework.
- Sixty five percent (65%) of the 2012 survey biomass, available for the 2013 fishery, is composed of new recruitment (48,969 t). The recruitment to the commercial biomass from the 2012 survey increased by 66.7% relative to the previous year.
- The residual biomass (26,028 t) from the 2012 survey decreased by 22.9% compared to 2011.
- The abundance of mature females remained high in 2012 relative to the low values observed during 2005 to 2009.
- The available predictions of recruitment of commercial-sized adult male crab indicate that they should remain at levels comparable to that of 2012 until the 2016 fishery.
- A risk analysis of catch options relative to reference points for the 2013 fishery is provided.

Fishery performance in 2012 in Area 12:

- The 2012 landings in Area 12 were 18,159 t (quota of 18,143 t).
- The CPUE (expressed as kg per trap haul (kg/th)) in 2012 (68.0 kg/th) increased compared to 2011 (53.0 kg/th).
- The incidence of soft-shelled crab remained low at 3.7% compared to 6.2% in 2011.

Fishery performance in 2012 in Area 19:

- The 2012 landings in Area 19 were 2,906 t (quota of 2,907 t).
- The CPUE in 2012 (178.1 kg/th) increased compared to 2011 (133.3 kg/th) and represents the highest value observed since records began in 1987.

- The incidence of white-crab decreased from 11.5% in 2011 to 4.5% in 2012.

Fishery performance in 2012 in Area 12E:

- In Area 12E, the landings were 185 t (quota of 251 t).
- The CPUE in 2012 (32.9 kg/th) slightly increased compared to 2011 (31.5 kg/th).
- The incidence of soft-shelled crab in 2012 decreased to 3.3%, compared to 8.4% in 2011.

Fishery performance in 2012 in Area 12F:

- The 2012 landings in Area 12F were 706 t (quota of 706 t).
- The CPUE in 2012 (41.8 kg/th) increased compared to 2011 (32.5 kg/th).
- The incidence of soft-shelled crab increased from 2.6% in 2011 to 9.4% in 2012.

BACKGROUND

Species Biology

Snow crab (*Chionoecetes opilio*) is a crustacean like lobster and shrimp, with a flat, almost circular, body and five pairs of spider-like legs. The hard outer shell is periodically shed in a process called molting. After molting, crabs have a soft shell for a period of 8 to 10 months. Soft-shelled crab is defined by shell hardness (<68 durometer units) and includes both new-soft (condition 1) and clean hard-shelled crab (condition 2). The term white-crab is used in the summer fishery of Area 19 because the newly-molted crabs have reached a relatively harder carapace than those observed during the spring fishery (Areas 12, 12E and 12F). White crab is defined by shell hardness <78 durometer units and includes both new soft (condition 1) and clean hard-shelled crab (condition 2).

Unlike lobsters, snow crabs do not continue to molt throughout their lives. Females stop growing when they acquire a wide abdomen for carrying eggs, which occurs at carapace widths (CW) less than 95mm. Males stop growing when they acquire large claws on the first pair of legs, which can occur at CWs between 40 and 150 mm. Females produce eggs that are carried beneath the abdomen for approximately 2 years. The eggs hatch in late spring or early summer and the newly-hatched crab larvae spend 12-15 weeks in the water column. At the end of this period, they settle on the bottom. It takes at least 8-9 years (post-settlement) for males to reach legal commercial size.

Fishery

Until 1994, the snow crab fishery in Area 12 (Figure 1) was exploited by 130 mid-shore crab harvesters from New Brunswick, Québec and Nova Scotia. Since 1997, the PEI coastal fishery, (formerly Areas 25/26) has been integrated into Area 12. In 2003, a portion of the coastal fishery off Cape Breton (formerly Area 18) was also integrated into Area 12. For the purpose of this assessment, Area 12 refers to the new management unit (Figure 1). The number of licenses in Area 12 was 273 in 2012.

In 1978, Area 19 (Figure 1) was established for the exclusive use of Cape Breton inshore fish harvesters with vessels less than 13.7 m (45 feet) in length. There were 158 licenses in Area 19 in 2012.

Areas 12E and 12F were introduced in 1995 as exploratory fisheries. In 2002, the status of Areas 12E and 12F was changed from exploratory to commercial fishing areas. There were 4 crab licenses in Area 12E (from New Brunswick, PEI and Québec) and 16 crab licenses in Area 12F (from Nova Scotia and Québec) in 2012.

The minimum legal carapace width for males is 95 mm, females are not harvested and soft-shell and white crab is not targeted by the fishery. Baited traps, constructed of wire or tubular steel, are used to catch crab, mainly on mud or sand-mud bottoms at temperatures ranging from -1 to 4.5°C, and depths ranging from 50 to 280m. The fishery takes place from spring to early summer in Areas 12, 12E and 12F and after June 30 in Area 19.

Management of these fisheries is based on quotas and effort controls (number of licenses, trap allocations, trap dimensions, and seasons). There are at-sea soft-shelled and white crab catch monitoring protocols which allow for closure of portions of each fishing area when the proportion of the catch of males of these carapace conditions exceeds 20%. The protocols are in place to maximize the yield and the reproductive potential of the resource.

Table 1. Number of licenses, vessels, traps, quotas and opening and closing dates in snow crab fishery by management area in the southern Gulf of St. Lawrence in 2012.

	Area				
	12	12E	12F	19	Southern Gulf
Number of licenses	273	4	16	158	451
Number of active vessels	295	4	16	98	413
Total number of traps allowed	29,838	450	1,290	1,699	33,277
Opening date	April 15	April 15	April 15	July 14	
Closing date	July 11	July 15	June 23	August 09	
Quota (t)	18,143	251	706	2,907	22,007
Landings (t)	18,159	185	706	2,906	21,956

The landings from the southern Gulf of St. Lawrence increased from 1969 to the present with three periods of high landings: 1981-1986, 1994-1995, and more recently 2002 to 2009 (Figure 2). The peak landing of the entire history was in 2005 at 36,118 t.

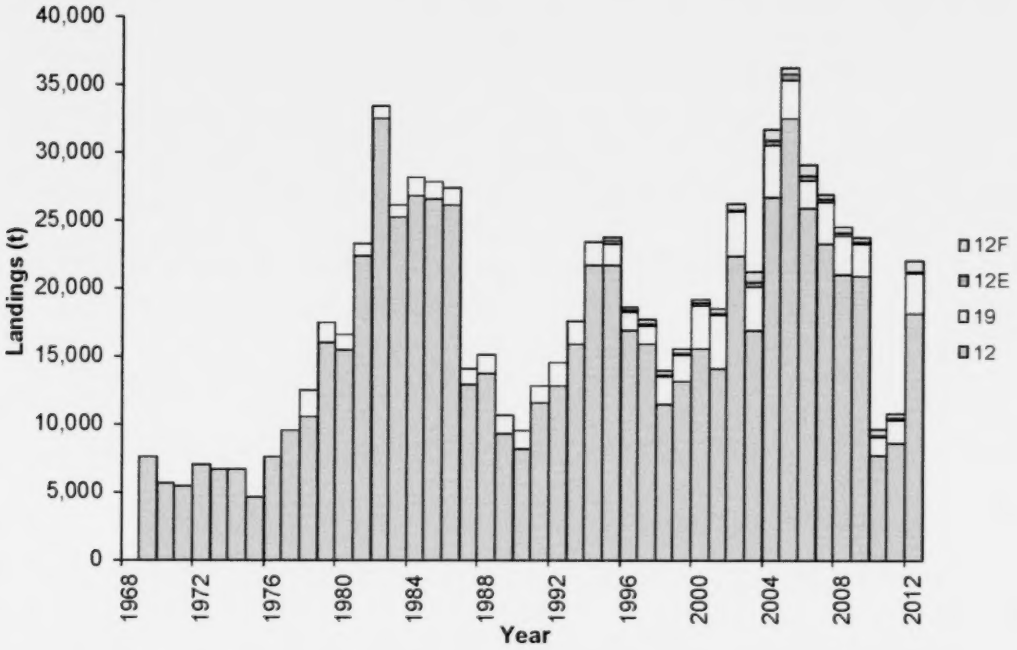

Figure 2: Landings (tons) in the southern Gulf of St. Lawrence snow crab fishery, 1969 to 2012.

The 2012 fishing season in Area 12 opened on April 15 and closed on July 11 with reported landings of 18,159 t (quota of 18,143 t) (Tables 1, 2; Figure 2). In accordance with the soft-shelled crab protocol, 7 of 323 grids were closed towards the end of the 2012 fishing season. The fishing effort estimated from logbooks has varied from 243,339 to 544,454 trap hauls between 1987 and 2009, but decreased considerably to 161,148 trap hauls in 2011, the lowest of the time series since 1987 (Table 2). The fishing effort was 267,044 trap hauls in 2012.

Table 2. Quota and landings (t), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 12, 2004 to 2012.

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Quota (t)	26,600	32,336	25,869	23,207	20,900	20,900	7,700	8,585	18,143
Landings (t)	26,626	32,363	25,889	23,243	20,911	20,896	7,719	8,618	18,159
CPUE (kg/trap-haul)	54.9	63.7	64.4	65.7	56.4	48.2	47.9	53.0	68.0
Effort (trap hauls)	484,991	508,053	402,702	353,775	370,762	433,527	161,148	162,604	267,044
Soft-shelled crab (%) in catches[1]	3.0	3.9	3.1	2.0	3.0	5.0	6.5	6.2	3.7
Grids closed (total of 323)	17	68	11	5	3	78	74	233	7

[1] The percentage is based on a durometer reading of 68. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

The 2012 fishing season in Area 19 opened on July 14 and ended on August 9 with reported landings of 2,906 t (quota of 2,907 t) (Tables 1, 3; Figure 2). The term white-crab, as used in the summer fishery of Area 19, is defined by shell hardness <72 durometer units. In accordance with the white crab protocol, no sector within Area 19 was closed during the 2012 fishing season. The fishing effort in Area 19 has varied from 16,733 to 55,977 trap hauls between 1987

and 2009, but considerably decreased to 11,138 trap hauls in 2010, the lowest of the time series since 1987. The effort in 2012 was 16,317 trap hauls.

Table 3. Quota and landings (t), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 19, 2004 to 2012.

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Quota (t)	5,092	2,878	2,000	3,074	3,002	2,433	1,360	1,703	2,907
Landings (t)	3,894	2,827	1,989	3,034	2,929	2,370	1,360	1,701	2,906
CPUE (kg/trap-haul)	68.9	68.1	84.4	71.3	76.3	71.4	122.1	133.3	178.1
Effort (trap hauls)	56,517	41,512	23,566	42,553	38,388	33,193	11,138	12,761	16,317
White crab (%) in catches[1]	7.9	7.7	6.1	7.4	9.0	11.6	6.4	11.5	4.5
Sectors closed[2]	4/4	0/4	2/4	0/4	4/4	9/9	4/9	0/9	0/9

[1] The percentage is based on a durometer reading of 72. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

[2] Total number of sector was changed from 4 to 9 sectors in 2009.

The 2012 fishing season in Area 12E began on April 15 and ended July 15 with reported landings of 185 t (quota of 251 t) (Tables 1, 4; Figure 2). The fishing effort in Area 12E increased from 1,825 trap hauls in 2010 to 5,623 trap hauls in 2012. In accordance with the soft-shelled protocol, no grids within Area 12E were closed during the 2012 fishing season.

Table 4. Quota and landings (t), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 12E, 2004 to 2012.

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Quota (t)	350	450	550	221	400	200	67	75	251
Landings (t)	349	449	411	220	187	67	50	76	185
CPUE (kg/trap-haul)	55.6	80.6	40.8	37.2	20.3	14.4	27.4	31.5	32.9
Effort (trap hauls)	6,277	5,571	10,074	5,914	9,232	4,653	1,825	2,413	5,623
Soft-shelled crab (%) in catches[1]	1.5	2.9	7.8	1.3	10.1	7.8	14.7	8.4	3.3
Grids closed (total of 8)	0	0	2	0	0	2	0	0	0

[1] The percentage is based on a durometer reading of 68. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

In Area 12F, the fishery in 2012 opened on April 15 and closed on June 23 with reported landings of 706 t (quota of 706 t) (Tables 1, 5; Figure 2). The fishing effort increased from 9,631 trap hauls in 2011 to 16,890 trap hauls in 2012. In accordance with the soft-shelled protocol, no sector within Area 12F was closed during the 2012 fishing season.

Table 5. Quota and landings (t), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 12F, 2004 to 2012.

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Quota (t)	808	480	815	408	585	465	420	314	706
Landings (t)	806	479	787	370	431	309	420	313	706
CPUE (kg/trap-haul)	74.8	93.7	55.9	30.2	27.8	22.0	29.3	32.5	41.8
Effort (trap hauls)	10,775	5,112	14,079	12,252	15,504	14,045	14,335	9,631	16,890
Soft-shelled crab (%) in catches[1]	0.6	0.8	3.5	2.4	7.3	11.4	8.6	2.6	9.4
Sectors closed (total of 3)	0	0	0	1	3	3	2	0	0

[1] The percentage is based on a durometer reading of 68. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

Catch per unit of effort (CPUE) expressed as kg per trap-haul (kg/th) is calculated from logbook data as the ratio of total landings (kg) to total effort (trap-hauls). In Area 12, the annual mean CPUE increased in 2012 (68 kg/th) compared to 2011 (Table 2; Figure 3). In Area 19, the CPUE has been increasing since 2009 and reached 178.1 kg/th in 2012 (Table 3, Figure 3). The CPUE in Areas 12E (32.9 kg/th) and 12F (41.8 kg/th) increased in 2012 compared to 2011 (Tables 4, 5; Figure 3).

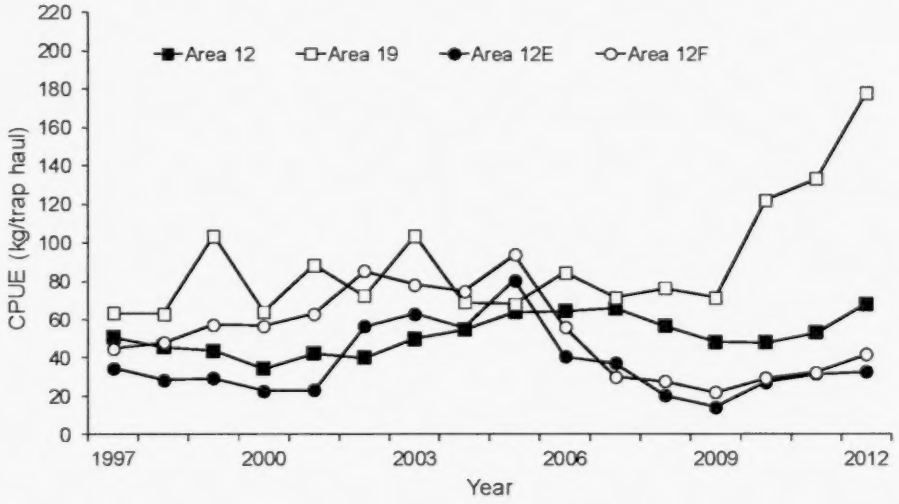

Figure 3: Catch per unit effort (kg per trap haul) in the southern Gulf of St. Lawrence snow crab fishery, Areas 12, 19, 12E and 12F, based on logbooks, 1997 to 2012.

Catch per unit of effort (CPUE) estimated from at-sea observer sampling of individual traps provides generally similar trends in CPUE to those estimated from logbooks (Figure 4).

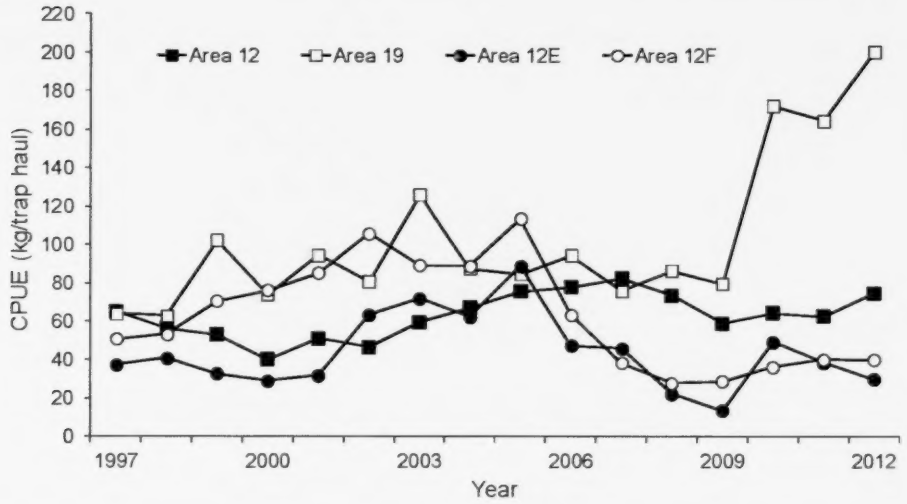

Figure 4: Catch per unit effort (kg per trap haul) in the southern Gulf of St. Lawrence snow crab fishery, Areas 12, 19, 12E and 12F, based on at-sea observer sampling, 1997 to 2012.

The percentage of soft-shelled crab and white crab is calculated using data collected from the at-sea observer program. The incidence of soft-shelled crab and white crab in catches is strongly influenced by the fishing strategy used by harvesters during the season, as well as commercial-sized adult crab abundance in the area.

The percentage of soft-shelled crab in Area 12 in 2012 was 3.7%, a decrease from 2011, and has remained low since 2004 (Table 2). In Area 19, the percentage of white crab was 4.5% in 2012, a decrease from 2011, and the second lowest since 2004 (Table 3). The percentage of soft-shelled crabs in Area 12E in 2012 was 3.3%, a large decrease from 2011 and in the low range of values since 2004 (Table 4). In Area 12F, the percentage of soft-shelled crabs in 2012 was 9.4%, an increase from 2011, and the second highest value in the 2004 to 2012 period (Table 5).

ASSESSMENT

The trawl survey was conducted using the procedure defined in the Snow Crab Assessment Methods Framework Science Review held during November 21 to 25, 2011, in Moncton, N.B. (DFO 2012a). Most of the recommended changes were implemented in the 2011 assessment including the expansion of the biomass estimation polygon to cover the entire area defined by the 20 to 200 fathoms depth contours (corresponding to the areal extent of bottom temperatures < 5 °C which are favourable for snow crab and encompassing the area of the southern Gulf of St. Lawrence biological unit) and the use of kriging with external drift based on catches in weights (each sampled commercial-sized adult male from a sampling station is converted into weight using the size-weight relationship). In 2012, a revised sampling design including the definition of a new sampling grid and selection of one station per grid cell, was used for the survey, in conformity with the recommendations of DFO (2012a). The change in methodology required a number of recalculations, completed for the 2011 assessment, including the area of the southern Gulf estimation polygon and associated areas (Figure 5), the time series of biomass estimates, the time series of exploitation rates, and the Precautionary Approach reference points (DFO 2012b, 2012c).

Snow crab in fishing areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.

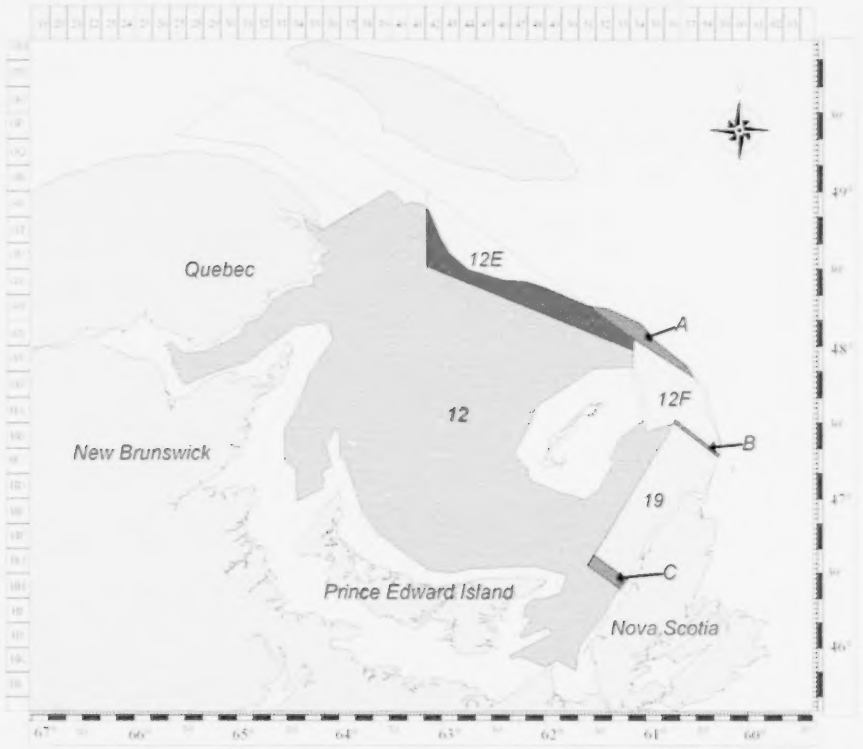

Figure 5: The estimation polygon of 57,840 km^2 used for the 2012 snow crab (Chionoecetes opilio) stock assessment in the southern Gulf of St. Lawrence (all of the coloured areas) and corresponding estimation polygons for the four crab fishing areas (12, 12E, 12F, and 19). The unassigned zone north of areas 12E and 12F (label A) and buffer zones (labels B and C) are also shown.

Stock Trends and Current Status in the Southern Gulf

Interpretation of stock status is based on inferences from abundance data from annual trawl surveys conducted during July to October, over the entire area of snow crab distribution in the southern Gulf. The surveys provide estimates of commercial biomass which are comprised of residual biomass (hard-shelled adult males of legal size remaining after the fishery) and recruitment biomass (soft-shelled adult males >= 95 mm CW (R-1) that will be available to the fishery the following fishing season). The snow crab trawl survey also provides indices of future male recruitment to the fishery (prerecruits defined as R-4, R-3 and R-2). The prerecruits R-4, R-3 and R-2 represent adolescent male crabs with a carapace width range of 56-68, 69-83, and larger than 83 mm, respectively. A portion of these crabs could be available to the fishery in 4, 3 and 2 years, respectively. An index of abundance of small male crab (34-44 mm CW) is also presented as an indicator of potential long-term recruitment. It takes at least six years for these small male crabs to reach the commercial size of 95 mm CW.

Spawning stock abundance consists of females (pubescent and mature). The term pubescent refers to females that will molt to maturity and mate the following year and become primiparous

females (first brood). The term 'multiparous' refers to females which are carrying a brood for the second time or more. The term 'mature females', includes primiparous and multiparous females.

The biomass of commercial-sized adult males in the southern Gulf of St. Lawrence from the 2012 trawl survey was estimated at 74,997 t with 95% confidence limits of 65,822 t to 85,086 t (Table 7; Figure 6). The estimated commercial biomass in the southern Gulf increased by 18.7% relative to 2011 (63,162 t; 95% C.I. 55,965 t – 71,022 t).

The recruitment to the fishery at the time of the 2012 survey was 48,969 t (95% C.I. 38,667 t to 61,173 t), comprising 65.3% of the commercial biomass (Table 7; Figure 6). The recruitment to the fishery in 2012 increased by 66.7% compared to the 2011 estimate. The residual biomass (carapace conditions 3 to 5) of commercial-sized male crab after the 2012 fishery was estimated at 26,028 t (95% C.I. 21,950 t to 30,641 t), a decrease of 22.9% relative to 2011 (Table 7; Figure 6).

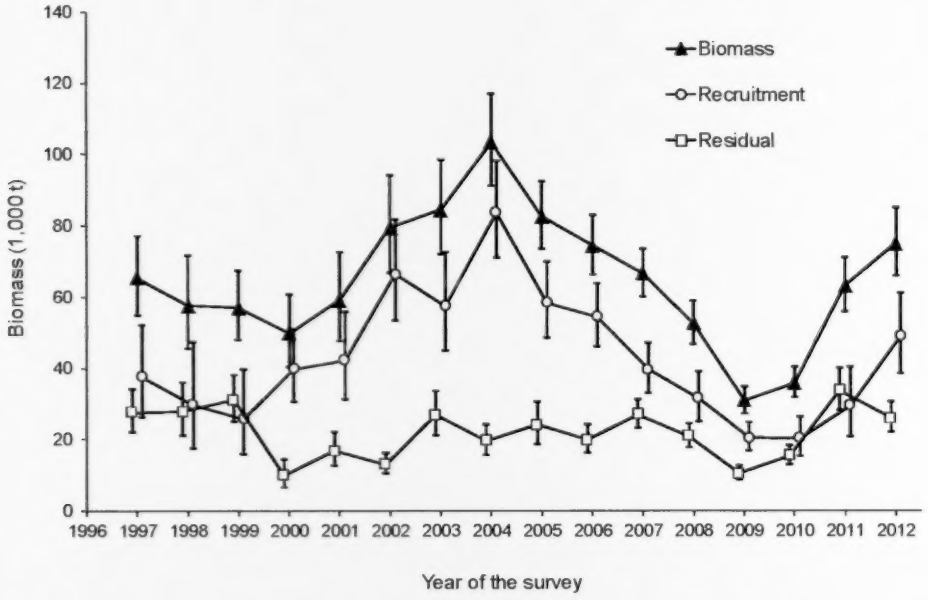

Figure 6: Total commercial biomass, recruitment commercial biomass, and residual commercial biomass (1,000 t; means with 95% confidence intervals) in the southern Gulf of St. Lawrence, 1997 to 2012.

Table 7. Total commercial, recruitment, and residual biomass (t; means with 95 % confidence intervals) of commercial-sized adult male crabs (>= 95 mm carapace width) in the southern Gulf of St. Lawrence, 1997 to 2012.

Year of the survey	Commercial Biomass	Recruitment Biomass	Residual Biomass
1997	**65,310** 54,801-77,239	**37,619** 26,376-52,064	**27,690** 21,995-34,407
1998	**57,595** 45,630-71,735	**29,818** 17,580-47,435	**27,775** 21,022-36,013
1999	**57,051** 47,946-67,376	**25,874** 15,918-39,818	**31,177** 25,051-38,346
2000	**49,823** 40,473-60,682	**39,845** 30,543-51,093	**9,977** 6,649-14,401
2001	**59,150** 47,740-72,460	**42,243** 31,198-55,942	**16,905** 12,657-22,125
2002	**79,559** 66,688-94,181	**66,481** 53,434-81,746	**13,075** 10,451-16,157
2003	**84,423** 71,964-98,410	**57,503** 44,809-72,679	**26,919** 21,223-33,674
2004	**103,429** 91,029-117,036	**83,702** 70,955-98,069	**19,726** 15,836-24,280
2005	**82,537** 73,487-92,387	**58,398** 48,417-69,824	**24,140** 18,726-30,632
2006	**74,285** 66,192-83,087	**54,371** 46,124-63,660	**19,914** 16,161-24,275
2007	**66,660** 60,183-73,638	**39,635** 33,089-47,092	**27,025** 23,354-31,106
2008	**52,564** 46,658-59,006	**31,555** 25,181-39,048	**21,010** 17,960-24,426
2009	**30,920** 27,237-34,959	**20,520** 16,848-24,754	**10,399** 8,560-12,516
2010	**35,795** 31,681-40,291	**20,351** 15,360-26,450	**15,444** 12,859- 18,394
2011	**63,162** 55,965-71,022	**29,394** 20,909-40,190	**33,768** 28,297- 39,985
2012	**74,997** 65,822-85,086	**48,969** 38,667-61,173	**26,028** 21,950- 30,641

A second fishery independent survey of the southern Gulf of St. Lawrence is used to provide an index of abundance of commercial-sized male crab. The multi-species research vessel bottom trawl survey, a stratified random design, has been conducted annually in September since the early 1970's although the estimation of commercial-sized male crab abundance is available only since 2001.

The September multi-species bottom trawl survey index shows similar trends in commercial male snow crab abundance between 2001 and 2012 as the biomass estimates from the dedicated snow crab trawl survey (Figure 7). The index of abundance declined from 2008 to 2009, remained low in 2010, increased in 2011 and remained high in 2012.

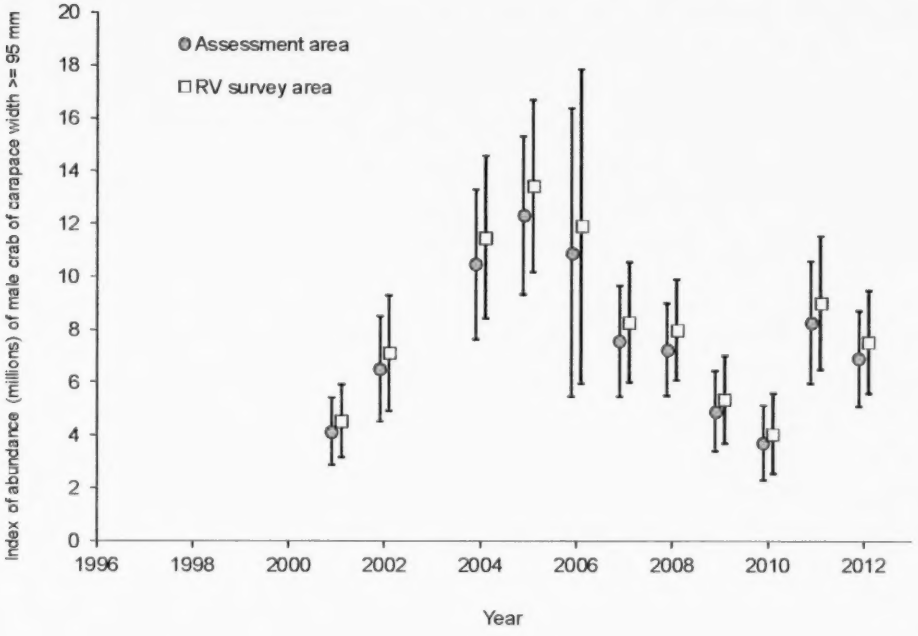

Figure 7: Index of trawlable abundance (numbers in millions, means and 95% confidence intervals) of male snow crab ≥95 mm carapace width in the September RV survey for 2001 to 2012. Series are presented for CCGS Teleost vessel catches based on a geographic area comparable to that used for the current snow crab assessment (grey shaded circle symbols) and for the entire RV survey area (open square symbols).

In the 2012 trawl survey, geographic concentrations of commercial-sized adult males were located in Bradelle Bank, in the central and southern parts of the Magdalen Channel and notably in the west of Cape Breton Island (Figure 8). The spatial distributions of commercial-sized adult males have varied annually during increasing and decreasing phases of the commercial biomass (Figure 9).

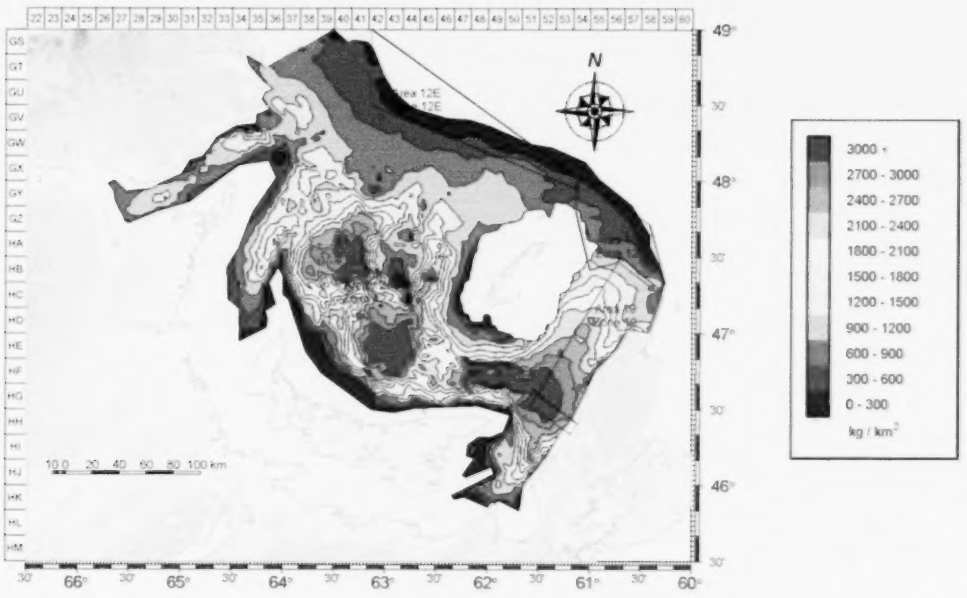

Figure 8: Density (kg per km^2) contours of commercial-sized adult male crab (≥95 mm CW) in the southern Gulf of St. Lawrence in 2012.

Figure 9: Density (kg per km^2) contours of commercial-sized adult male crab (≥95 mm CW) in the southern Gulf of St. Lawrence, 2003 to 2011.

As requested by DFO Fisheries and Aquaculture Management, the 2012 commercial biomass estimates in snow crab fishing areas (12, 19, 12E and 12F), two buffer zones (between areas 12F and 19, between areas 12 and 19) and the unassigned zone (north of areas 12E and 12F), as shown in Figure 5, are summarized in Table 8. The majority of biomass was found in Area 12, followed by Area 19, 12F, 12E, buffer zones, and the unassigned zone (Table 8).

Table 8. Estimates of commercial biomass (t; means and 95% confidence intervals) in 2012 for the southern Gulf of St. Lawrence estimation polygon of 57,840 km^2 and for each of the snow crab fishing areas 12, 19, 12E, 12F, the buffer zones, and the unassigned zone. Labels refer to those in Figure 5.

Areas	Surface area (km^2)	Commercial biomass (t)	
		Mean	95% confidence interval
Southern Gulf [1]	57,840	74,997	65,822 - 85,086
Area 12	48,028	64,238	56,254 - 73,031
Area 19	3,833	7,668	5,944 - 9,736
Area 12E	2,443	577	68 - 2,214
Area 12F	2,438	1,450	480 - 3,409
Subtotal of crab fishing areas	56,742	73,933	
Unassigned zone above 12E and 12F (label A)	674	22	0 – 164
Buffer zone 19 / 12F (label B)	112	109	34 - 268
Buffer zone 12 / 19(label C)	310	913	635 - 1,274
Total of individual area estimates [1]	57,838	74,977	

[1] Small differences in the sum of the individual area estimates compared to the southern Gulf estimates are due to rounding of intermediate calculation precisions

The exploitation rate in the southern Gulf of St. Lawrence is calculated as the ratio between the catch of the fishery in the year of the assessment and the commercial biomass estimated from the trawl survey in the previous year. In 2012, the exploitation was 34.8%. The exploitation rates varied between 21% and 45% from 1998 to 2011 (Figure 10).

Total mortality is calculated as one minus the ratio of the residual biomass estimated from the survey in the year of the assessment and the biomass available to the fishery as estimated in the previous year's survey. In 2012, total mortality was estimated at 58.8% (Figure 10). The total mortality has varied between 45.8% and 82.5% since 1997, except for 2011 when it was estimated at 5.6% (Figure 10).[1]

Over the time series, the estimated commercial biomass from the survey was on average 29% higher than the sum of the residual biomass and the landings of the following year. This difference (termed non-fishing directed mortality) could be attributed to a number of factors including misattribution of recruitment and residual groups, variability in survey estimates, natural mortality, non-directed fishery induced mortalities, as well as crab movement in and out of the sampling area. The commercial biomass estimate from the trawl survey of 2011 was 24.0% higher than the sum of the residual biomass from the trawl survey in 2012 plus the landings in 2012. However, the commercial biomass estimate from the trawl survey of 2010 was 24.3% lower than the sum of the residual biomass from the trawl survey plus the landings in 2011. The difference for that year had not been observed before and this discrepancy is discussed further in the section on uncertainties.

[1] *Erratum*: February 20, 2013 – Calculation method for the total mortality corrected.

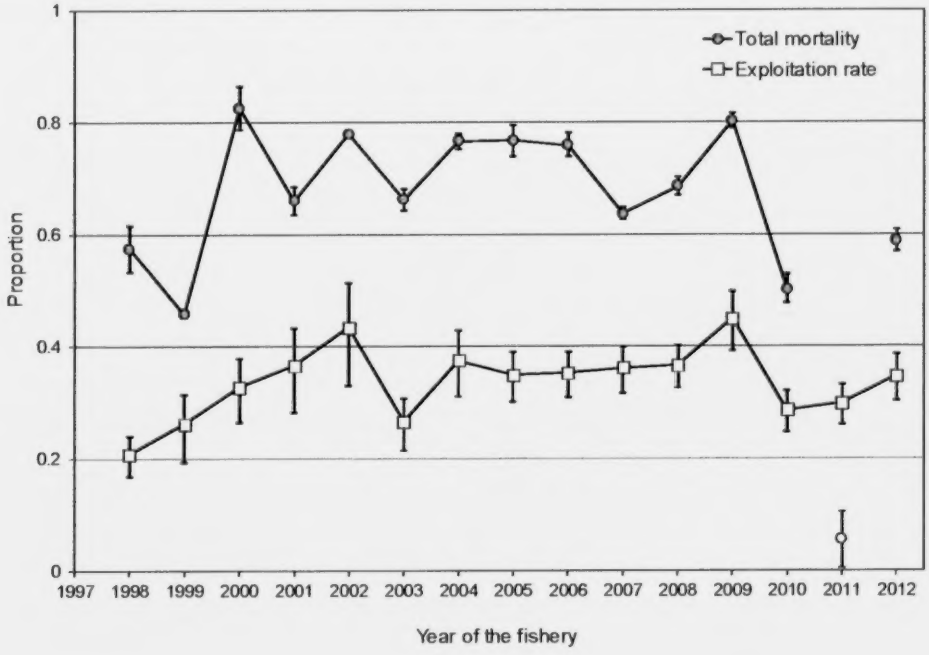

Figure 10: Exploitation rates (± 95% confidence intervals) by the fishery and total mortality of commercial-sized adult male snow crab in the southern Gulf of St. Lawrence, 1997 to 2012. The 2011 total mortality point is isolated from the series due to uncertainties in the components of the 2011 survey.

Based on abundances of adolescent males of R-2, R-3 and R-4 from recent surveys, the trend in the recruitment of commercial-sized adult male crab to the fishery is anticipated to remain stable at the levels comparable to those observed in 2012 until the 2016 fishery (Figures 11 and 12). The index of abundance of small male crab (34-44 mm CW) from the trawl survey in 2012 is comparable to the index estimated since 2007 (Figure 13).

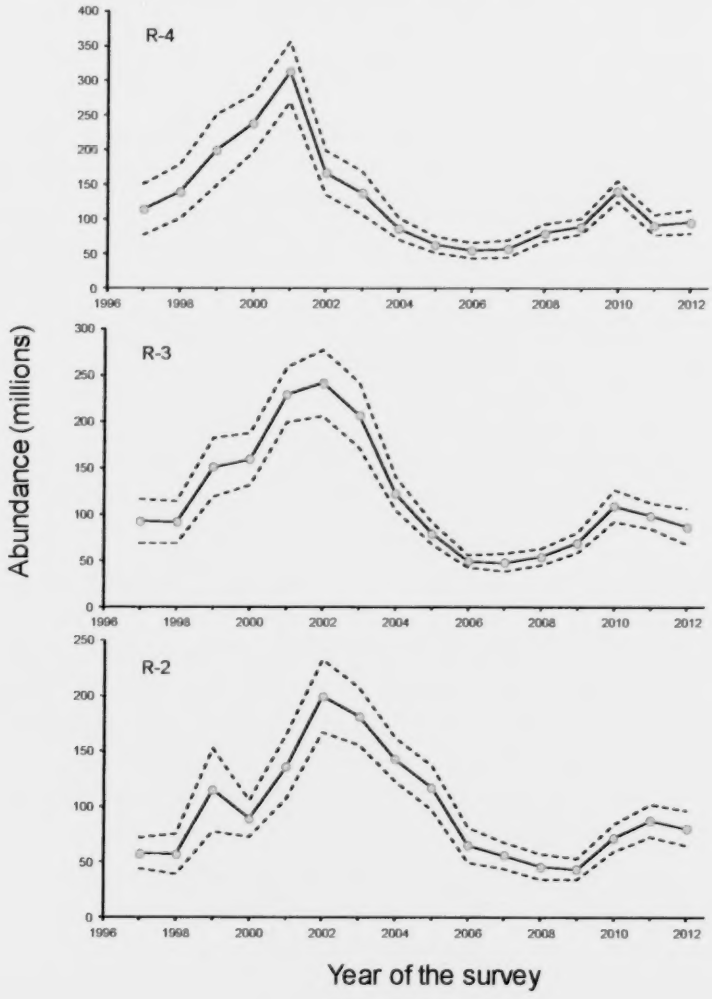

Figure 11: Estimated abundances (millions; means and 95% confidence intervals) of R-4 (upper panel), R-3 (middle panel) and R-2 (lower panel) adolescent male crabs in the southern Gulf of St. Lawrence for the survey years 1997 to 2012.

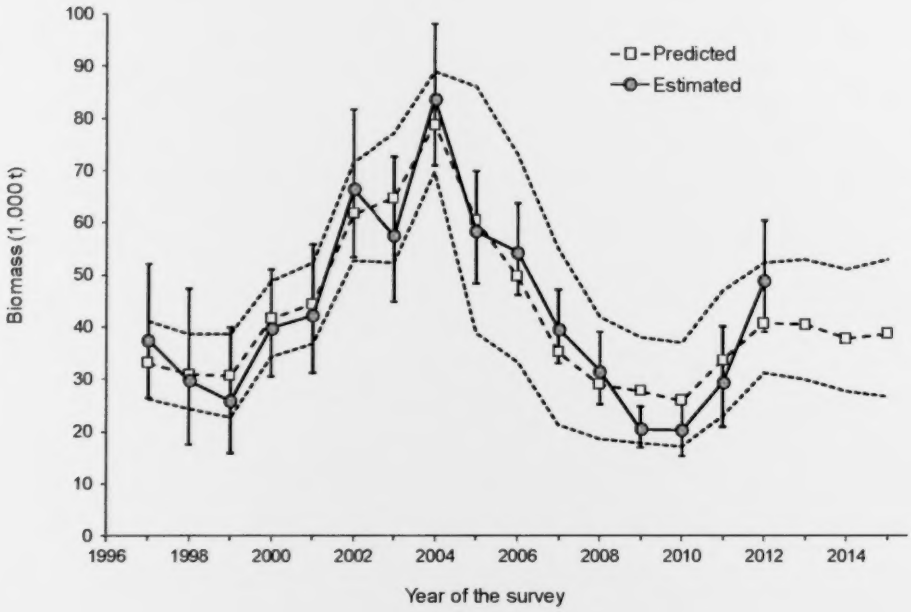

Figure 12: Estimated (grey circle symbols are the means with 95% confidence interval vertical bars) and predicted (open square symbols are the means with the 95% confidence interval bands as dashed lines) biomasses of R-1 (adult male crabs >= 95 mm carapace width of carapace condition 1 and 2) snow crab in the year of the survey, 1997 to 2015. The predicted abundances are based on a relationship to the estimated abundances of R-2 (adolescent male crab larger than 83 mm CW) in the previous year. Predictions of R-1 biomasses for 2013 to 2015 are based on abundances of R-2, R-3, and R-4 estimated in 2012 and shown in Figure 11.

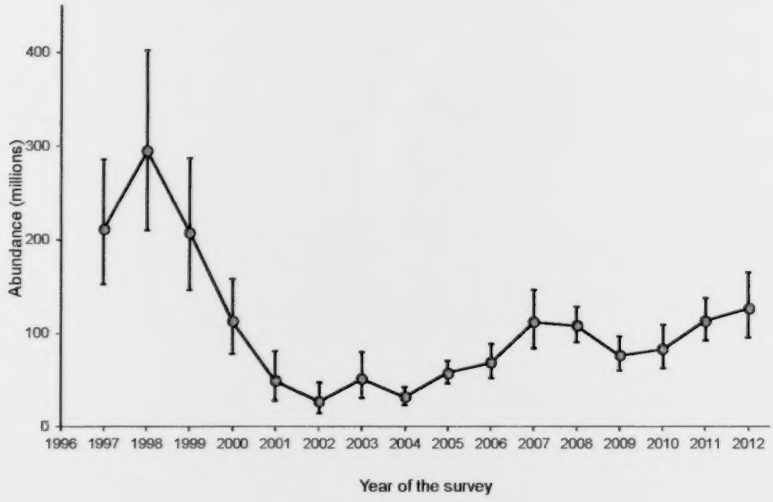

Figure 13: Index of abundance (means with 95% confidence intervals, numbers in millions,) of small male crab of 34 to 44 mm CW, based on the trawl surveys conducted in the southern Gulf of St. Lawrence, 1997 to 2012.

Reproduction

The abundance of mature females remained high in 2012 relative to the low values observed during 2005 to 2009 (Figure 14). There is an increase of pubescent females observed in the 2012 survey, which suggests that the abundance of mature females will continue to increase in the near future (Figure 14).

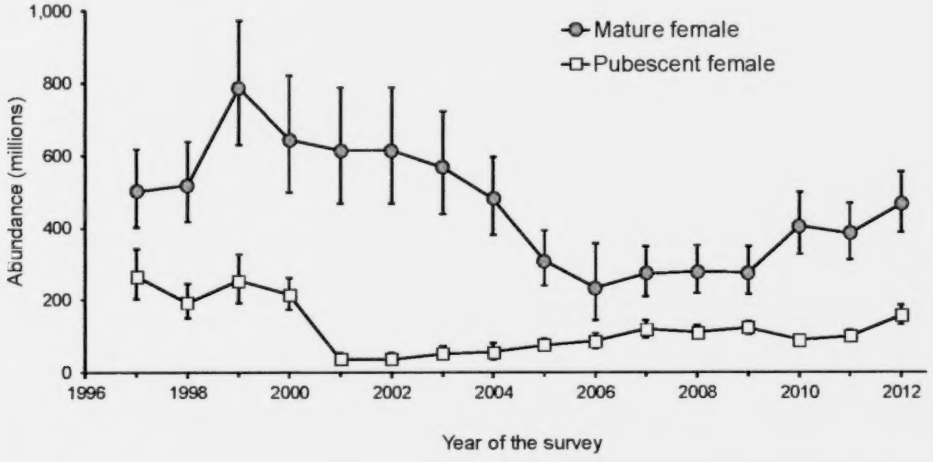

Figure 14: Estimated abundances (millions; means and 95% confidence intervals) of mature female (grey circle symbols) and pubescent females (open square symbols) in the southern Gulf of St. Lawrence based on the trawl surveys during 1997 to 2012.

Sources of Uncertainty

A Snow Crab Assessment Methods Framework Science Review was conducted in November 2011 to address concerns about the variations in survey design and sample coverage, the standardization of area swept, and the area of the estimation polygon to be used (DFO 2012a). Following the review, it was agreed that the biomass time series from 1997 to the present was a coherent time series to be used in assessing stock status and providing catch advice. Further work was required to determine if the earlier part of the time series between 1989 and 1996 for which survey coverage was much less than the coverage from 1997 to the present, could also be used to assess snow crab abundance in the southern Gulf of St. Lawrence. This work has begun.

The estimate of residual biomass in 2011 was abnormally high relative to the expected value from the 2010 survey and the fishery in 2011. This discrepancy may be due to a number of factors including misattribution of recruitment to the residual crab category in 2011. It was noted that the abundance of skip molters in the eastern portion of the southern Gulf of St. Lawrence was high in 2010. These crabs would have molted much earlier (four months) than normal molters (Hebert et al. 2012). Due to the earlier molt, these crabs become harder with some epibionts on the carapace sooner in the following year than normal molters. This could become a serious issue when the survey period is prolonged towards late fall. Another possibility is the underestimation of commercial biomass in 2009 and 2010 and / or overestimation of biomass in 2011, which could be verified using a secondary fishery independent survey such as the September multi-species survey. Other factors such as the movement of unaccounted amount of crab from outside the southern Gulf of St. Lawrence biological unit cannot be ignored.

Temperature in the southern Gulf varies annually. In recent years, the temperatures have been above normal and the index of suitable habitat for crab has declined. These changes in temperature can affect a number of life history processes including molting and growth, reproduction, and larval development. The impacts of warming conditions on the snow crab life history are not well understood.

CONCLUSIONS AND ADVICE

Within the Precautionary Approach (PA) framework (DFO 2009), the Limit Reference Point for biomass (B_{lim}) defines the critical / cautious zones and an upper stock reference (B_{USR}) delimits the cautious / healthy zones on the stock status axis. A removal rate limit reference point (F_{lim}) defines the maximum removal rate in the healthy zone. The recommended change in methodology as per the Snow Crab Assessment Methods Framework Science Review (DFO 2012a) required the recalculation of the time series of biomass estimates and the Precautionary Approach reference points. The rescaled upper stock reference point (B_{USR}) is 41,400 t of commercial-sized adult males of all carapace conditions as estimated from the trawl survey (DFO 2012b). Commercial-sized adult male crabs of all carapace conditions are available for the fishery in the year following the trawl survey. The rescaled biomass limit reference point (B_{lim}) value is 10,000 t (DFO 2012b). The biomass limit reference point was chosen as the lowest biomass of hard shelled commercial-sized adult males which produced good recruitment rates of small male crabs of 34-44 mm CW (referred to as Instar VIII) (DFO 2010). The rescaled removal reference point (F_{lim}) is 34.6% (DFO 2012b). The southern Gulf of St Lawrence commercial biomass estimate from the trawl survey should be used for evaluating catch options relative to the defined reference points.

The trajectory of stock abundance (biomass of commercial-sized adult male crab from the snow crab trawl survey in year t - 1) versus exploitation rate on this biomass in the fishery of year t is shown in Figure 15. The commercial biomass has varied between 30,920 t and 103,429 t during 1998 to 2012. Over this same period, exploitation rates have varied between 20.8% and 45.0%. The estimated biomass from the 2012 snow crab survey, which would be available to the fishery in 2013, is 74,997 t (95% CI 65,822 – 85,086 t). The 2012 survey biomass estimate is in the healthy zone. To be consistent with the existing Precautionary Approach policy (DFO 2009), when the stock is in the healthy zone, the exploitation rate should not exceed 34.6%.

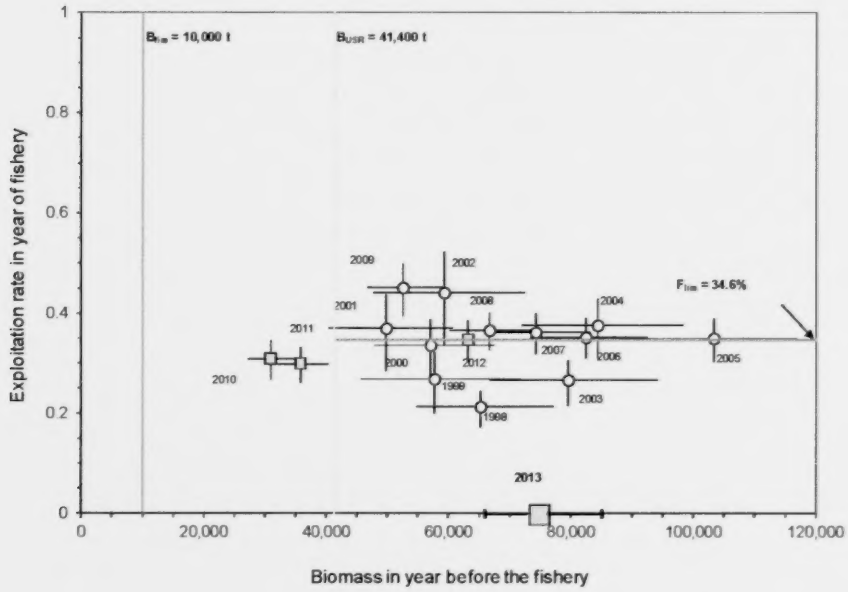

Figure 15: Trajectory of stock abundance (biomass of commercial-sized adult male crab as estimated from the trawl survey in year before the fishery) versus exploitation rate in the fishery year. Year of the fishery is labeled on the figure. Error bars are 95% confidence intervals. White circle symbols are biomass and exploitation rate levels used to define the reference points. The grey squares are the years when the reference points were used within the PA to decide on the fishery quota. The biomass estimate available for the 2013 fishery (with 95% confidence interval) is also shown.

A risk analysis was developed relative to various catch options in 2013 (Table 9; Figures 16 and 17). The decision rules to put in practice the Precautionary Approach framework remain to be defined.

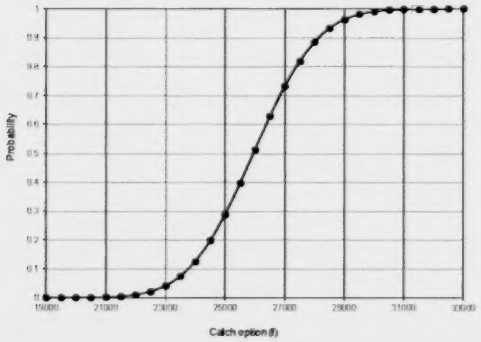

Figure 16: Risk analysis for the southern Gulf of St. Lawrence snow crab fishery showing the probabilities of exceeding F_{lim} for different catch options in 2013.

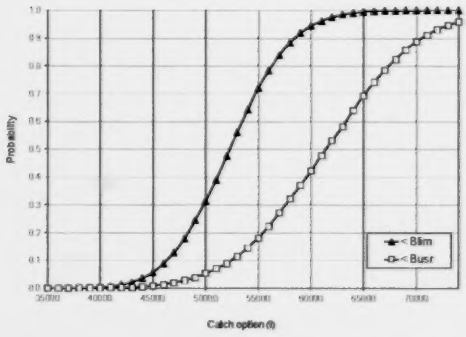

Figure 17: Risk analysis for the southern Gulf of St. Lawrence snow crab fishery showing probabilities of hard-shell commercial-sized adult male biomass in 2013 falling below B_{lim} (black triangle symbols) and of commercial-sized adult male biomass in 2013 being below B_{USR} (open square symbols) after the 2013 fishing season for different catch options in 2013.

Table 9. Risk analysis for different catch options in 2013 for the southern Gulf of St. Lawrence snow crab fishery showing probabilities of exceeding F_{lim}, of the hard-shell commercial-sized adult male remaining biomass falling below B_{lim}, and of the total commercial-sized adult male biomass being below B_{USR} post-fishery in 2013.

	Probability		
Catch option (t)	> F_{lim} = 34.6%	< B_{lim} = 10,000 t	< B_{USR} = 41,400 t
21,000	0	0	0
21,500	0	0	0
22,000	0.01	0	0
22,500	0.02	0	0
23,000	0.04	0	0
23,500	0.07	0	0
24,000	0.12	0	0
24,500	0.20	0	0
25,000	0.29	0	0
25,949	0.50	0	0
27,000	0.73	0	0
28,000	0.89	0	0
29,000	0.96	0	0
30,000	0.99	0	0
31,000	1	0	0

OTHER CONSIDERATIONS

Environmental Considerations

In 2012, near-bottom temperatures over most of Area 12, 12E and 12F were above normal and temperatures in Area 19 were above normal only in the north-eastern half while in the southern part, they were around normal values. The north-eastern part of Area 12 warmed up in 2012 compared to 2011, the western part of Area 12 and Area 19 cooled down and temperatures in Areas 12E and 12F were similar to 2011. The warmer bottom waters of 2012 resulted in a below normal Southern Gulf snow crab habitat index (bottom area with temperatures from –1 to 3 °C). In 2012, the habitat index slightly increased from 2011 and was 3.7% below the 1980-2010 average (Figure 18). However, the mean temperature (1.4°C) within the defined snow crab habitat area (-1 to 3 C) in 2012 increased compared to 2011 by about 0.2°C (Figure 18). The 2012 mean temperature was the highest of the 42 year data series with 1982 exhibiting the second warmest value (Figure 18). The 2012 value is significantly higher than the long term mean and is above the 1999-2002 and 2005-2007 warm periods. The mean temperature has also been above normal over the last four years (Figure 18).

Snow crab is a stenothermic species with a preference for colder water temperatures. A temperature regime shift from cold to warm may have impacts on population dynamics of snow crab such as shortened reproductive cycles, increased per capita fecundity, increased size at maturity, greater natural mortality, spatial contraction of habitat, and skewed sex ratio for reproduction. The stock may be more vulnerable to commercial fishing pressure under climate-driven changes resulting in increasing temperatures. Furthermore, the outcome of climate change on snow crab population dynamics can be relatively abrupt and even detrimental, and the direction of the effect may be difficult to predict (Sainte-Marie et al. 2008).

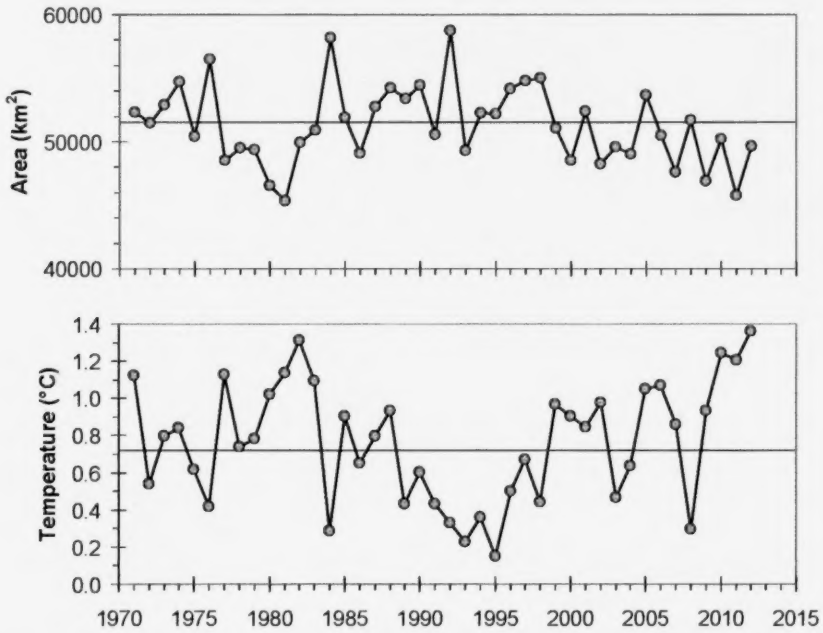

Figure 18: Snow crab temperature habitat area index (km²) that encompasses water temperatures of -1 to 3 °C (upper panel) and the mean temperature (°C) within the temperature area index (lower panel) in the southern Gulf of St. Lawrence, 1971 to 2012.

SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, regional advisory meeting of January 30-31, 2013 on the assessment of the status of the southern Gulf of St. Lawrence snow crab stock. Additional publications from this process will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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